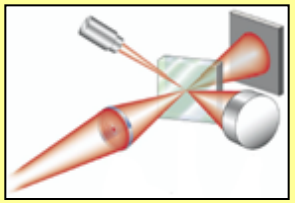
NSLS-II Overview

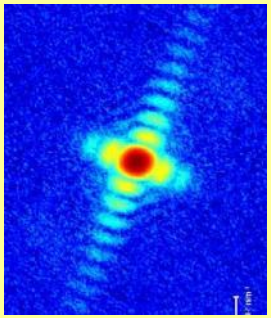
Steve Dierker
Associate Laboratory Director for Photon Sciences
NSLS-II Industrial Research Workshop
April 8-9, 2014

NSLS-II: A Powerful New Photon Microscope

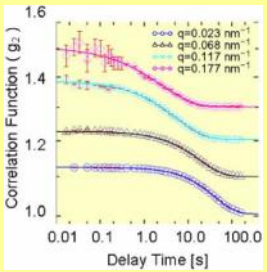
New Capabilities



Nanoprobes



Diffraction Imaging



Coherent Dynamics

Highly optimized x-ray synchrotron delivering:

- extremely high brightness and flux
- exceptional beam stability
- advanced instruments, optics, and detectors

Providing best-in-class capabilities for:

- imaging systems with nanoscale resolution
- determining chemical reactivity in-situ in real time

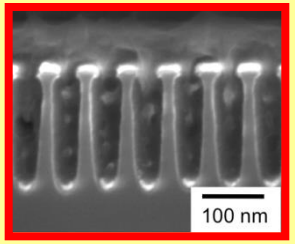
Enabling studies of:

- interfaces and nanostructures
- electronic excitations and chemical reactivity
- in-situ chemical, magnetic, and biological imaging
- materials synthesis, catalytic reactions, superconductors, and magnets at extremes of temperature, pressure, and magnetic field

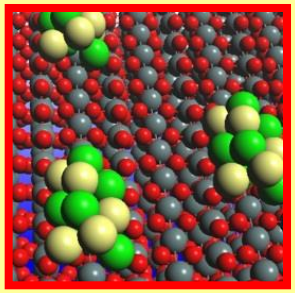
Resulting in scientific advances in:

- clean, renewable, and affordable energy
- molecular electronics
- high temperature superconductors
- structure-based drug design

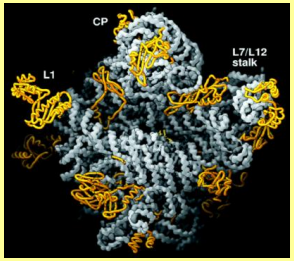
New Science



Nanoscience



Nanocatalysis



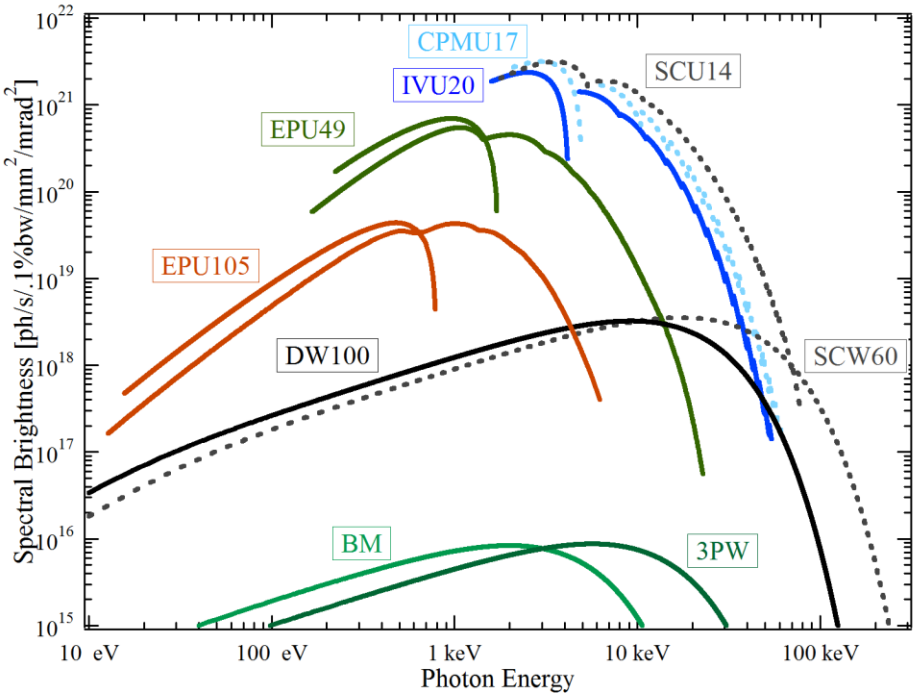
Life Science

NSLS-II Design Features

Best-in-class brightness & flux from far infrared to hard x-rays

Design Parameters

- 3 GeV, 500 mA, top-off injection
- Circumference 791.5 m
- 30 cell, Double Bend Achromat
  - 15 high-β straights (9.3 m)
  - 15 low-β straights (6.6 m)



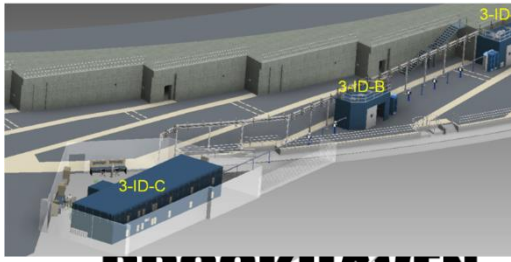
Novel design features:

- Damping wigglers
- Soft bend magnets
- Three pole wigglers
- Large gap IR dipoles
- Long beamlines
- Ultra-high stability

Ultra-low emittance for high brightness and small source size

- ε_x, ε_y = 0.6, 0.008 nm-rad
- Diffraction limited in vertical at 12 keV
- Small beam size: σ_y = 2.6 μm, σ_x = 28 μm, σ'_y = 3.2 μrad, σ'_x = 19 μrad

Pulse Length (rms) ~ 15 psec



NSLS-II Project Scope

Accelerator Systems

- Storage Ring (~ ½ mile in circumference)
- Linac and Booster Injection System

Conventional Facilities

- Ring Building and Service Bldgs (400,000 gsf)
- 5 Laboratory/Office Bldgs designed to promote interaction & collaboration among staff & users (190,000 gsf)

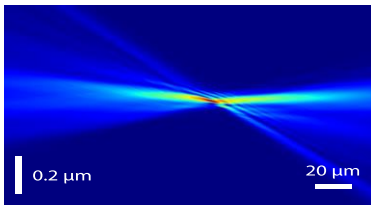
Experimental Facilities

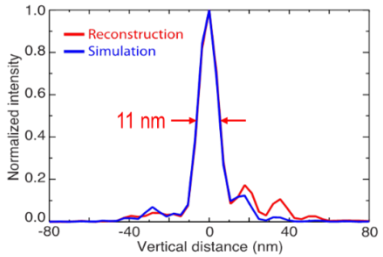
- Initial suite of seven insertion device beamlines
- Capable of hosting at least 58 beamlines

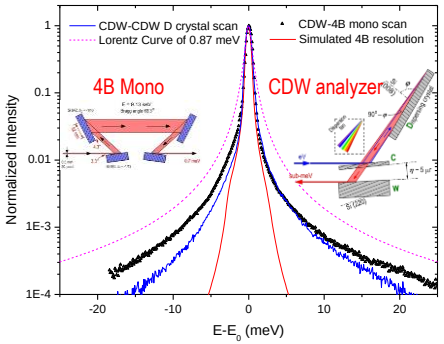
Research & Development

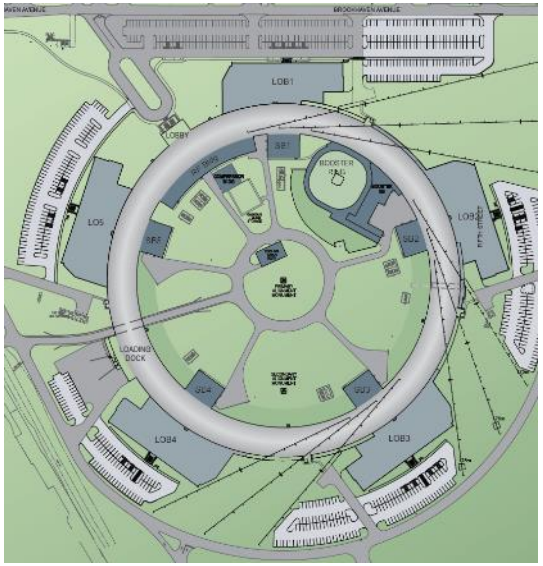
- Advanced optics & accelerator components

Total Project Cost $912M









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BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Key Project Milestones

Aug 2005	**CD-0**, Approve Mission Need	(Complete)
Jul 2007	**CD-1**, Approve Alternative Selection and Cost Range	(Complete)
Jan 2008	**CD-2**, Approve Performance Baseline	(Complete)
Jan 2009	**CD-3**, Approve Start of Construction	(Complete)
Feb 2009	Contract Award for Ring Building	(Complete)
Aug 2009	Contract Award for Storage Ring Magnets	(Complete)
May 2010	Contract Award for Booster System	(Complete)
Feb 2011	1st Pentant Ring Building Beneficial Occupancy	(Complete)
Feb 2011	Begin Accelerator Installation	(Complete)
Feb 2012	Beneficial Occupancy of Experimental Floor	(Complete)
Mar 2012	Start LINAC Commissioning	(Complete)
Nov 2013	Start Booster Commissioning	(Complete)
Mar 2014	Start Storage Ring Commissioning	(Complete)
Aug 2014	Early Project Completion; Ring Available to Beamlines	
Jun 2015	**CD-4**, Approve Start of Operations	

June 15, 2009

October 13, 2010

April 26, 2012

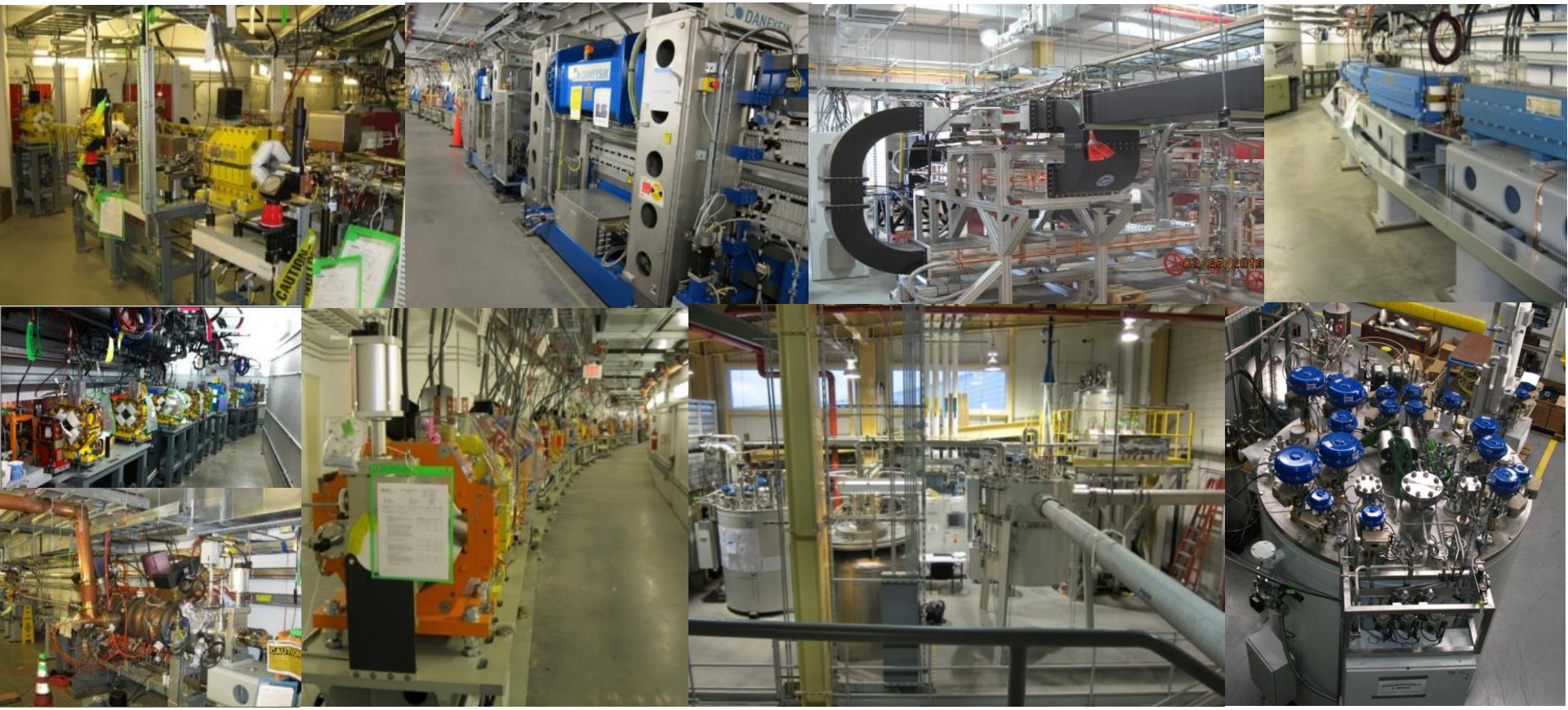
Status of NSLS-II Project

- Excellent progress
- Project is 95% complete as of end of February 2014
- On schedule for early completion in August, 2014
- On budget with substantial scope added to maximize science

Aerial View of NSLS-II

June, 2013

Accelerator Systems



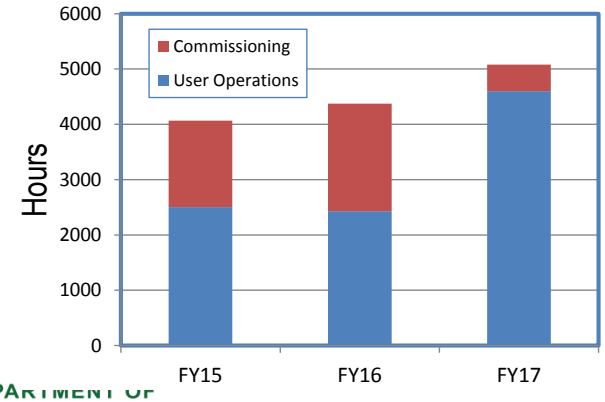
- Accelerator Systems are 96% complete
- Injector commissioning is complete
- Start of storage ring commissioningstarted on Mar 26, 2014
- Stored beam achieved on Apr 5, 2014
- Completion of accelerator systems: Aug 2014

Early Storage Ring Operations

	FY15	FY16	FY17
Insertion Device, Front-end and Beamline	1563	1947	480
Accelerator Studies [h] (49-60/fortnight)	850	946	1046
Maintenance [h] (12h/week)	425	473	523
Shut downs [h]	2160	2160	1440
High current commissioning [h]	565	320	202

Scheduled User Beamtime [h]	2943	2698	4842
Operations reliability (overall)	0.85	0.9	0.95
Actual User Time w/Beam [h]	2502	2428	4600

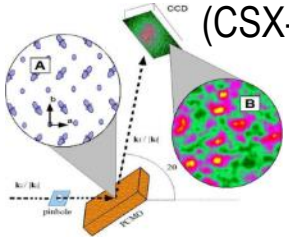
Maximum Beam Current [mA]	300	400	500



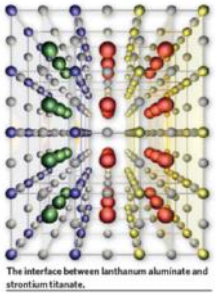
- Challenge: Significant time will be required in FY15 & FY16 to install and commission insertion devices, front ends, and beamlines
- Mitigation: Optimize installation schedule and coordinate with beamline operations

NSLS-II Project Beamlines

Coherent Soft X-ray Scattering (CSX-1)



World-leading coherent flux XPCS, CDI

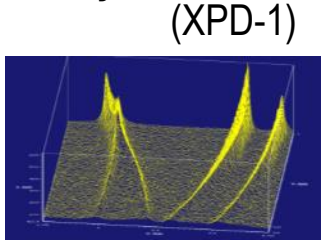


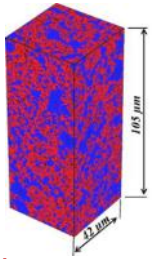
Fast Switching Polarization (CSX-2)

Resonant magnetic scattering, spectroscopy, XMCD

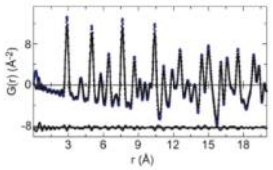
Imaging & dynamics in strongly correlated and magnetic materials

X-ray Powder Diffraction (XPD-1)





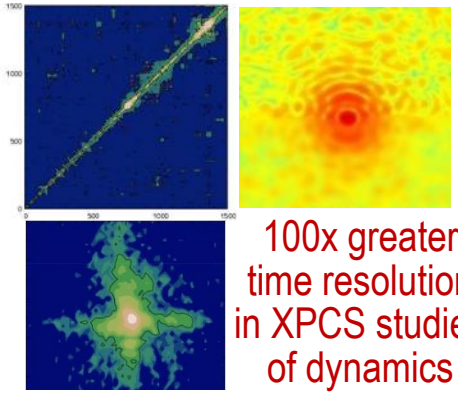
PDF (XPD-2)



Powder diffraction, scattering, PDF 30-80 keV

Time-resolved in-situ in-operando extreme conditions
Understanding complex nanostructured materials

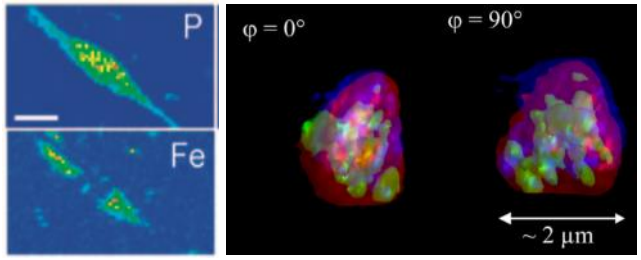
Coherent Hard X-ray Scattering (CHX)



100x greater time resolution in XPCS studies of dynamics

Non-equilibrium and heterogeneous dynamics in soft matter, at buried interfaces, biomaterials, glasses, driven systems

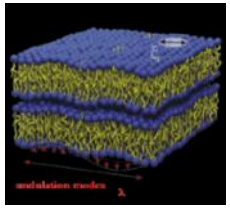
Sub-um Resolution X-ray Spectroscopy (SRX)

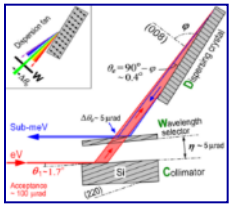


World-leading spectroscopy in sub-100 nm spot

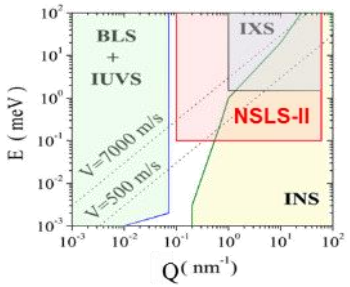
3D chemical imaging and speciation at the nanoscale

Inelastic X-ray Scattering (IXS)



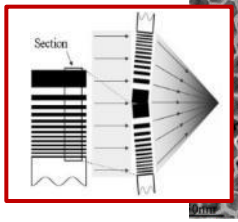


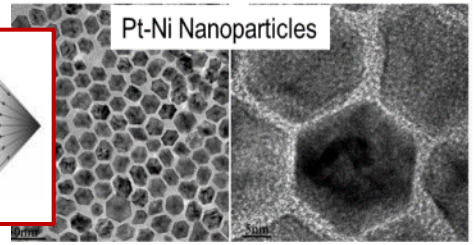
~1 meV baseline
~0.1 meV ultimate goal



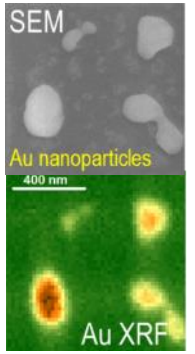
THz dynamics in liquid, glassy, and crystalline materials with nanoscale inhomogeneities

Hard X-ray Nanoprobe (HXN)





100m long beamline
~10 nm baseline
~1 nm ultimate goal



Nanoscale imaging with fluorescence and diffraction

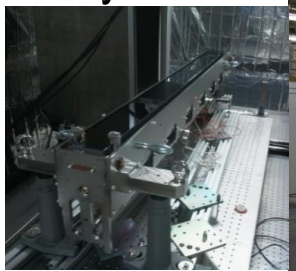
NSLS-II Project Beamline Status










- 18 Hutch Structures Erected at NSLS-II
- Utility installations 95% complete
- Beamline optics installation underway
- Last optics due in April 2014
- 80% complete overall
- On track for early finish

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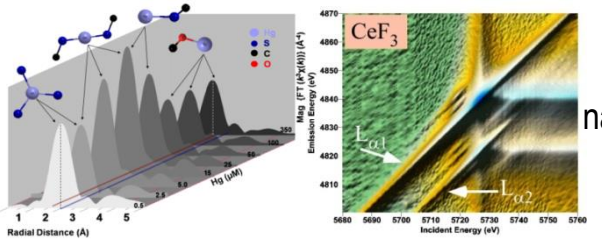
NSLS-II Experimental Tools (NEXT) Beamlines

DOE-BES funded $90M MIE project - Operations to begin 1QFY17

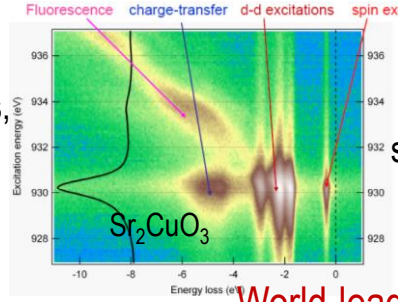
Inner Shell Spectroscopy (ISS)



In-situ, time-resolved, element specific studies of nanocatalysts, mettalloenzymes, environmental contaminants, batteries, and fuel cells

Time resolved XAS with high E-resolution and at ultra-dilute concentrations

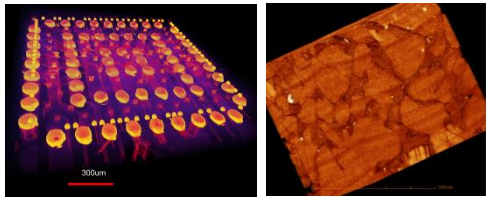
Soft Inelastic X-ray Scattering (SIX)



Elementary excitations (magnons, phonons and orbitons) in nanoscale samples $(100\ nm)^3$ w/ applications to superconductivity, nanocatalysts, energy storage materials

World-leading soft x-ray energy resolution

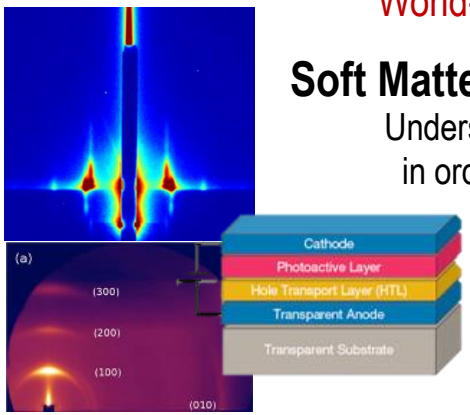
Full-field X-ray Imaging (FXI)



semiconductor failures $CaCO_3$ drilling

Real-time 3D imaging of natural and man-made materials in working environments

High speed TXM w/ 30 nm resolution

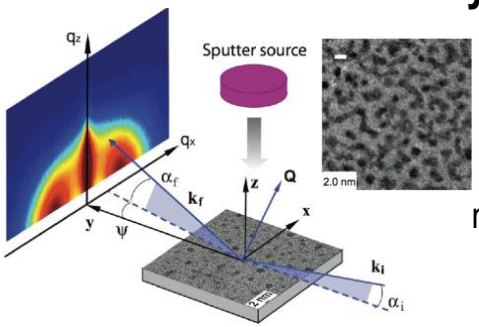


Soft Matter Interfaces (SMI)

Understanding self-assembly of nanomaterials in order to create new hierarchical materials with tailored functionality

In-situ real-time studies of solid/liquid/vapor interfaces of complex materials

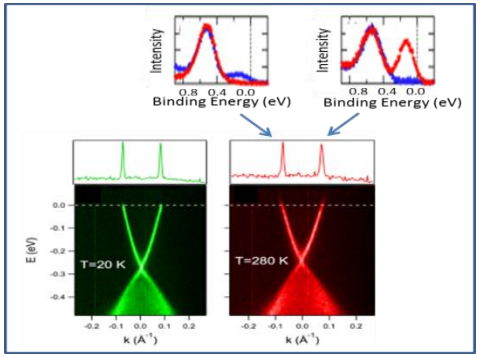
In-Situ & Resonant X-Ray Studies (ISR)



Powerful capabilities for in-situ, real-time growth, atomic structure of surface and interfaces, magnetic/orbital scattering, domain imaging, high magnetic fields

Integrated materials physics studies

Electron Spectro-Microscopy (ESM)



Advancing photoemission to characterize electronic structure of functional materials w/ high spatial resolution

Sub-meV nano-ARPES
LEEM/PEEM

Advanced Beamlines for Biological Investigations with X-rays

ABBIX Project - NIH funded $45M - Operations to begin 1QFY16

Frontier Macromolecular Crystallography (FMX)

Studies of enzymatic pathways of cellular and microbiological processes

Studies of drug-target interactions of new and improved pharmacologically effective compounds

Tunable 1µm beam of high intensity for micro-crystallographic studies of small crystals and large unit cells

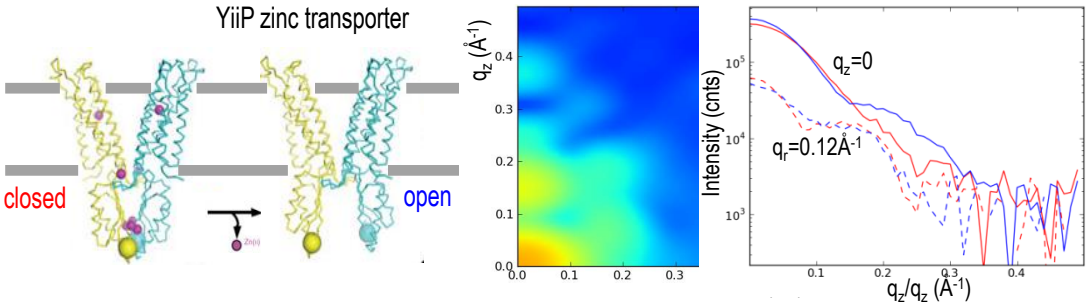
Highly Automated Beamline for Macromolecular Crystallography (AMX)

Atomic structure of large protein and nucleic acid complexes, including membrane proteins

Highly automated to support remote access and extensive experimental searches

Precise structure determinations with unprecedented throughput

High Brightness X-ray Scattering for Life Sciences (LIX)



Grazing incidence scattering from 2D solutions of proteins embedded in near-native membranes

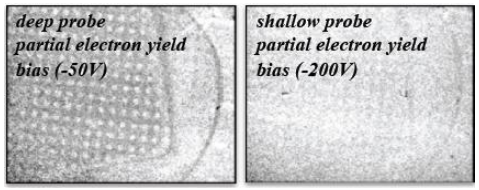
1µm beam scanning probe imaging and tomography of biological tissues

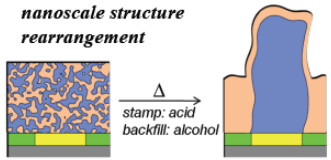
Time-resolved solution scattering down to 10µs

Partner Beamlines

Operations to begin FY16

Spectroscopy Soft & Tender (SST-1, SST-2) - NIST





Nanoscale imaging of the structure and chemistry of buried layers and interfaces of real device architectures

6 unique world class NEXAFS/XPS stations (2 full field microscopes, 2 automated high-throughput, and 2 in-situ high pressure) with two undulators covering soft (100 eV – 2.2 keV) and tender (1 – 7.5 keV) x-rays

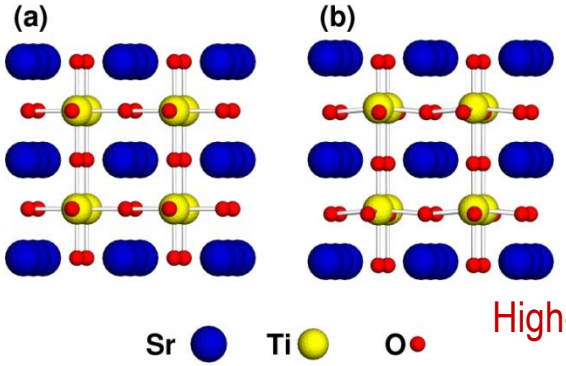
New X-ray Photoelectron Spectroscopy Microscope being developed for SST

NYSBC Microdiffraction Beamline (NYX) - NYSBC

Membrane proteins relevant to neurobiology and metabolic disorders, and protein-protein interactions in signaling complexes and protein-nucleic acid complexes in transcription or replication

Diffraction from micron sized crystals and optimized for anomalous scattering with high energy resolution at low energies (3.5 – 17.5 keV)

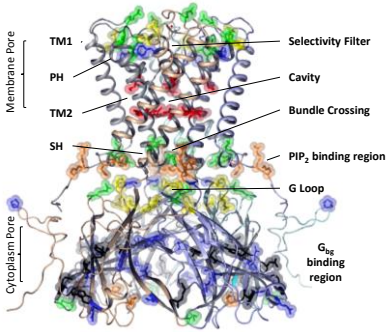
Beamline for Materials Measurements (BMM) - NIST



Strain engineering studies of electronic thin films, high throughput XAFS studies of chemical reactions and catalysts, phase transitions under controlled environmental conditions

High-throughput, high-quality hard x-ray absorption and diffraction

X-ray Footprinting (XFP) - CWRU



Steady state and time-resolved X-ray hydroxyl-radical mediated Protein and Nucleic Acid Footprinting

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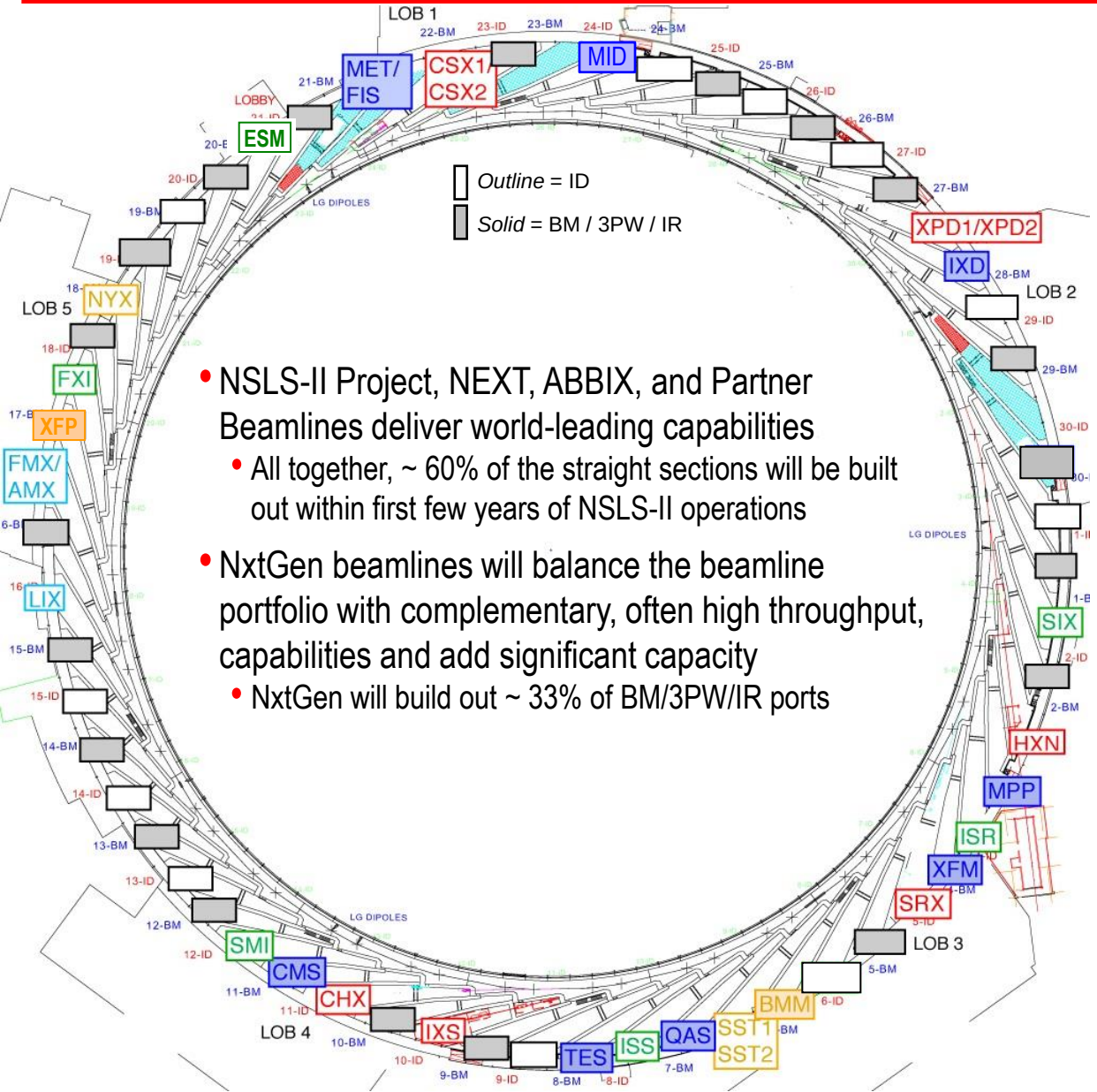
NxtGen Beamlines
Operations to begin FY15-FY17

- Bending magnet, three pole wiggler, and infrared beamlines are needed at NSLS-II to provide complementary capabilities, including high throughput, and add significant capacity
- These will also serve to transition much of the existing NSLS user community & their scientific programs to NSLS-II
- NxtGen will cost effectively transfer eight such beamlines from NSLS to NSLS-II by reusing components from one or more NSLS beamlines

Complex Materials Scattering (CMS)
Magneto, Ellipso, High Pressure IR (MET/FIS)
Metrology & Instrum Development (MID)
In-situ X-ray Diffraction Studies (IXD)

Materials Physics & Processing (MPP)
Quick X-ray Absorption and Scattering (QAS)
Tender X-ray Absorption Spectroscopy (TES)
X-ray Fluorescence Microscopy (XFM)

NSLS-II Beamline Portfolio
30 Beamlines Under Development



- NSLS-II Project, NEXT, ABBIX, and Partner Beamlines deliver world-leading capabilities
  - All together, ~ 60% of the straight sections will be built out within first few years of NSLS-II operations
- NxtGen beamlines will balance the beamline portfolio with complementary, often high throughput, capabilities and add significant capacity
  - NxtGen will build out ~ 33% of BM/3PW/IR ports

8 NSLS-II Project Beamlines
Inelastic X-ray Scattering (IXS)
Hard X-ray Nanoprobe (HXN)
Coherent Hard X-ray Scattering (CHX)
Coherent Soft X-ray Scat & Pol (CSX1, CSX2)
Sub-micron Res X-ray Spec (SRX)
X-ray Powder Diffraction (XPD1, XPD2)

6 NEXT Beamlines (DOE MIE)
Photoemission-Microscopy Facility (ESM)
Full-field X-ray Imaging (FXI)
In-Situ & Resonant X-Ray Studies (ISR)
Inner Shell Spectroscopy (ISS)
Soft Inelastic X-ray Scattering (SIX)
Soft Matter Interfaces (SMI)

3 ABBIX Beamlines (NIH)
Frontier Macromolecular Cryst (FMX)
Flexible Access Macromolecular Cryst (AMX)
X-ray Scattering for Biology (LIX)

5 Partner Beamlines
Spectroscopy Soft and Tender (SST1, SST2)
Beamline for Mater. Measurements (BMM)
Microdiffraction Beamline (NYX)
X-ray Footprinting (XFP)

8 NxtGen Beamlines
Complex Materials Scattering (CMS)
Magneto, Ellipso, High Pressure IR (MET/FIS)
Metrology & Instrum Development (MID)
In-situ X-ray Diffraction Studies (IXD)
Materials Physics & Processing (MPP)
Quick X-ray Absorption and Scattering (QAS)
Tender X-ray Absorption Spectroscopy (TES)
X-ray Fluorescence Microscopy (XFM)

NSLS & NSLS-II Beamlines

		FY12	FY13	FY14	FY15	FY16	FY17
Hard X-ray Diffraction	Powder Diffraction	X7B, X10B, X14A, X16C					IXD
					XPD-1		
	Diffraction - Extreme Cond.	X17B2/B3/C					
					XPD-1		
	Rapid Acquisition PDF	X17A					
						XPD-2	
	Microbeam Diffraction	X13B					
					CHX		
	Energy Dispersive	X17B1					
Hard X-ray Scattering	SAXS/ WAXs/ GISAXS/ Liq	X6B, X9, X10A, X22B, X27C				TES	
					CMS		
							SMI
	Resonant/In-situ	X20A, X20C, X21, X22C					MPP
							ISR
	Inelastic				IXS		
	XPCS/CDI				CHX		
Soft X-ray Scattering	Scattering / XMCD	U4B, X1A2, X1B, X13A					
					CSX-2		
	Coherent Scattering				CSX-1		
	Inelastic						SIX
Spectroscopy	Hard X-ray	X3A, X3B, X10C, X11A,			QAS		
		X11B, X18A, X18B, X23A2			BMM		
							ISS
	Tender X-ray	X15B, X19A				TES	
					SST-2		
	Soft / UV	U7A, U5UA, U12A, U13B,				SST-1	
		X1A1, X24A					ESM
	IR	U2A, U4IR, U12IR					MET/FIS
Imaging	Hard X-ray nanoprobe				HXN, SRX		
							XFN
	Hard X-ray microprobe	X26A, X27A					XFM
	Hard X-ray Nano CT	X8C					FXI
	Hard X-ray Micro CT, DEI	X2B, X15A					
	Instrum, Top, Det Char	X19C, X27B					MID
	Tender X-ray					TES	
					SST-2		
	CDI				CHX		
	Soft/ UV Full-field	U5UA				SST-1	
							ESM
	IR Microprobe, Full-field	U2B, U10B				IRI	
Structural Biology	Protein Crystallography	X3A, X4A, X4C, X6A, X12B,				FMX, AMX	
		X12C, X25, X29				NYX	
		X26C				SM3	
	Solution Scattering					LIX	
	X-ray Footprinting	X28C			XFP		

Key
NSLS
NSLS-II Project
NEXT
ABBIX
Partner
NxtGen
Other

- New NSLS-II capabilities will spawn new programs and user communities
- Clear transition path to NSLS-II for many NSLS programs but multi-year gap in some cases
  - Working with other facilities to assist users during transition
- All NSLS-II beamlines will be in high demand
- Working to fully build out NSLS-II as rapidly as possible
  - Dramatically enhances capabilities of DOE-BES light source portfolio
  - Significantly enhances capacity: NSLS-II will host over 4000 users/year when fully built out

NSLS-II: The Next 10 Years

Vision: Enable and conduct broad range of high-impact science programs at NSLS-II

World Class Science

- Create a vibrant environment
- Develop breakthrough capabilities
- Identify new research areas
- Attract world class scientists

High Impact Technologies

- Identify pre-competitive industrial R&D
- Match problems with expertise
- Develop experiments/instruments
- Provide solutions

Discovery Research → Use-inspired Basic Research → Applied Research → Technology Maturation & Deployment

- Strategy
  - World class scientists pioneering new research areas
  - Develop and operate world-class photon sciences beamlines with breakthrough capabilities
  - Advance enabling technology in optics, detectors, instrumentation, engineering, methodologies, and analyses
  - Leverage BNL facilities & core programs and external groups to increase impact and better serve user community
  - Catalyze innovation by facilitating university-industry-government collaborations via focused workshops with topical communities identifying needs and opportunities
- Organizing communities in Consortia to achieve greater productivity and impact
  - Facilitate formation of cross-cutting science consortia (e.g. Synchrotron Catalysis Consortium) to integrate science across beamlines, provide specialized instrumentation, and expand user community through outreach

NSLS-II

CFN / Nanoscience

New York Blue

Long Island Solar Farm

NSLS-II: A Bright Future

- NSLS-II continues to make excellent progress
  - On track for early completion, on budget, substantial added scope
  - 30 beamlines under development
- Commissioning proceeding well & early operations plans well developed
- Development of first experiments underway & user community engaged
- Looking forward to fast ramp up to an exciting science program

U.S. DEPARTMENT OF ENERGY

Goals of This Workshop

- Provide an update on user access policies and ways to partner with NSLS-II
- Provide an update on the schedule for ramping up NSLS-II capabilities, including short-term and long-term plans for NSLS-II beamlines and plans for the transition period between NSLS and NSLS-II
- Discuss industrial research needs for facility access, scientific support, and synchrotron techniques
- Establish a framework for industry user support at NSLS-II that matches the needs of industrial research
- Capture the outcomes in a white paper

Agenda

Day 1: Presentations

- BNL and PS management
- Representatives from other light sources
- Representatives from industry community
- NSLS-II tour

Day 2: Break-out Discussions

- Petrochemicals/Catalysis (Simon Bare)
- Polymers (Soft Materials) (Alex Norman)
- Microelectronics (Eugene Lavely)
- Advanced Materials (Stan Petrash)
- Pharmaceuticals (Sean McSweeney)
- Report summary from each facilitator